



National Laboratory/University Perspective on Existing RD&D

GridWorks RD&D Planning Workshop October 20-21, 2004

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.





Outline

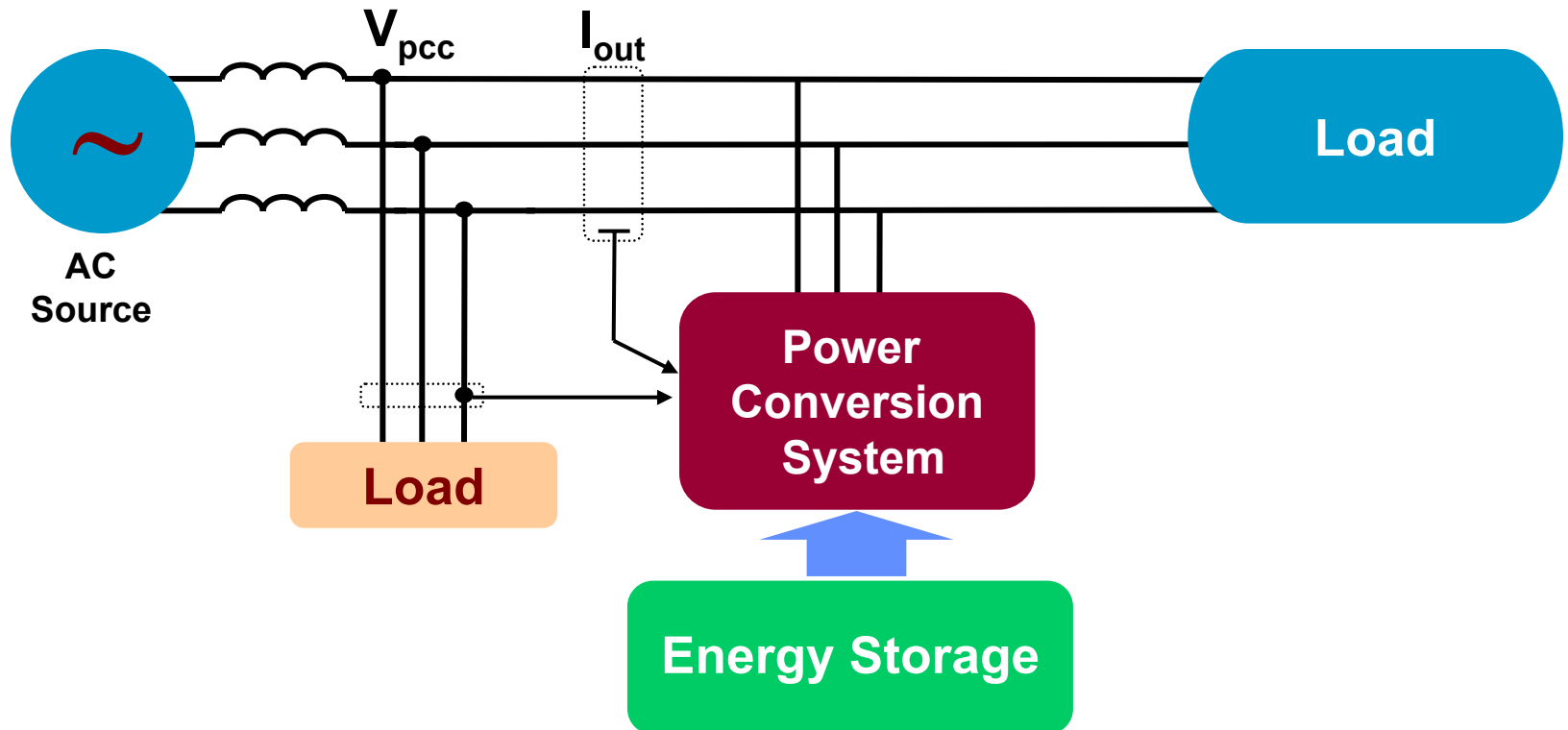
- **Introduction**
- **Power Electronics Issues and Needs**
- **Project Examples**
- **Conclusion**



DOE Energy Storage Program

- **Funded by DOE's Office of Transmission & Distribution Energy Storage Program (Dr. Imre Gyuk)**
- **Sandia National Laboratories manages program for DOE**
- **Develop advance energy storage technologies that increase the security, reliability, performance, and competitiveness of electricity generation, transmission, distribution, and use in both grid-connected and off-grid systems**
- **Focus: Integrated energy storage systems using batteries, SMES, flywheels, supercapacitors, other advanced energy storage devices and power electronics**
- **Encourage program participation by industry, academia, research organization and regulatory agencies**

Power Conversion Systems



Power Conversion System (PCS) is a key element of the ESS

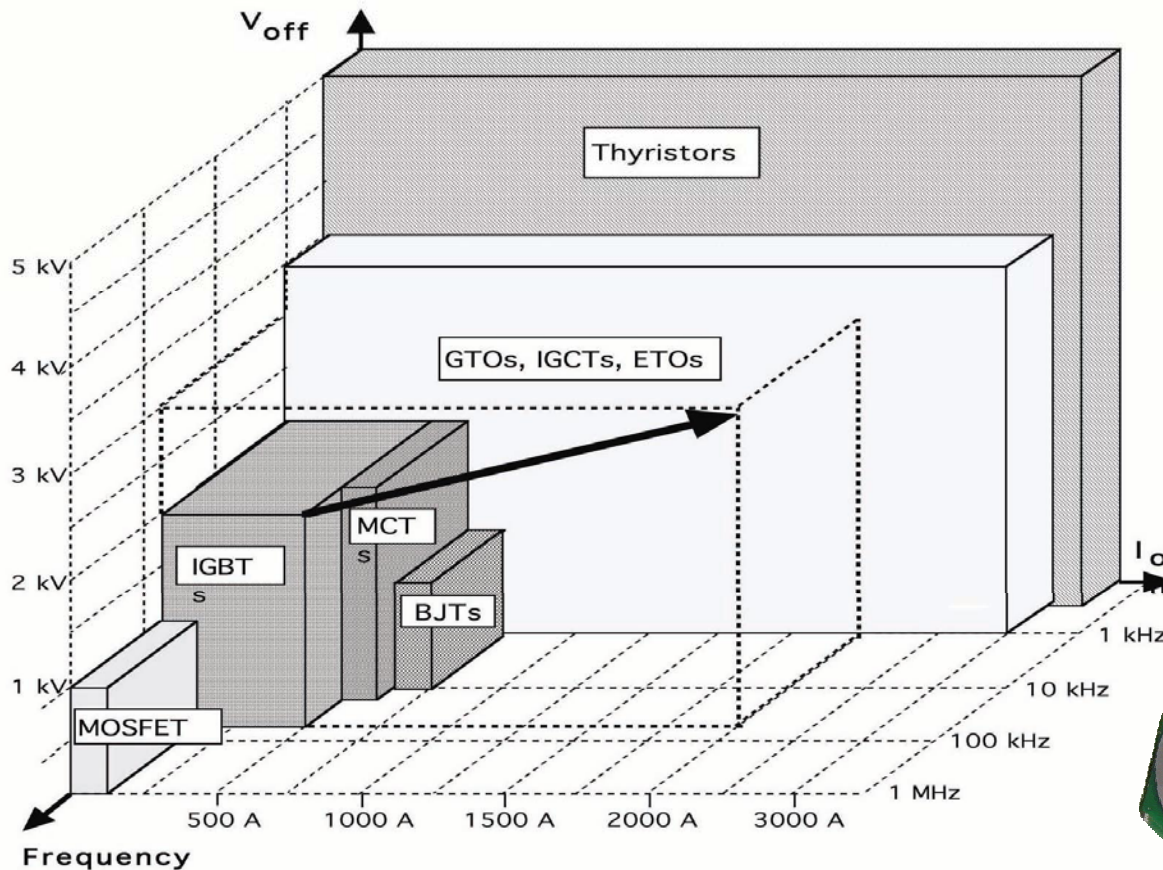


Power Electronics Issues Today

- **Cost** Lower cost, standardization/modularity
- **Reliability** Reliable active & passive components
- **Semiconductor Switches** High power & faster switching devices
High-temp devices & passive components
- **Thermal Management** Advance cooling methods
- **Controls** Advance digital controls/master control
for multiple converters
- **Footprint** High density converters
- **Power Quality** Low harmonic voltage & currents
- **Electromagnetic Interference** Low interference

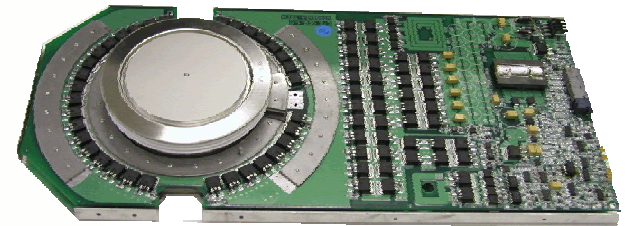
Cost and Reliability are key

Summary of Silicon Power Device Capabilities



Trends:

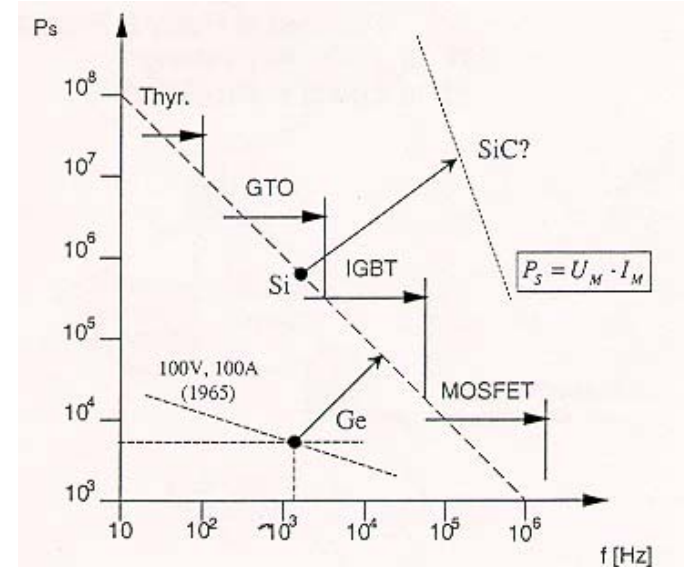
- Increase Voltage/Current Ratings
- Increase Switching Frequency
- Lower Switching Losses
- Improve Drives
 - Self Protection & Diagnostics
- Lower Inductance



An Example: Emitter Turn-Off Thyristor (ETO)

Wide Band Gap Device Research

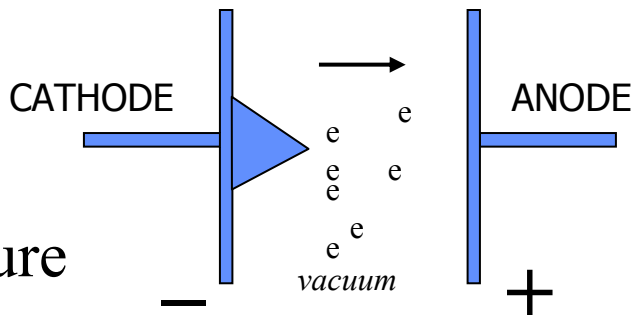
- **Advantages**
 - High Frequency Operation
 - Less Switching Losses
 - Higher Blocking Voltages
 - Higher Operating Temperature
- **Disadvantages**
 - Expensive
 - Limited Current Level
- Major funding from DARPA and ONR
- DOE/Sandia – FY05 SBIR Solicitation (WBG Device Application)
- ORNL – WBG Device Application
- Today's Manufacturers
 - Cree Inc. and Infineon Technologies (SiC Schottky Diodes)



Source: Power Electronics Technology at the Dawn of the New Millenium – Status & Future

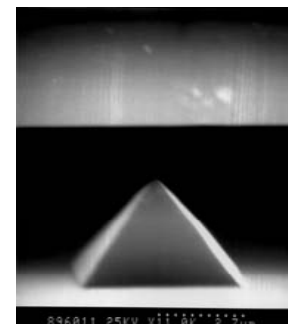
Chemical Vapor Deposition Diamond Research

- ➔ 5 X's higher voltage
- ➔ 5X's higher temperature of operation
- ➔ 4X's higher thermal conductivity than copper
- ➔ Fast Switching in a vacuum

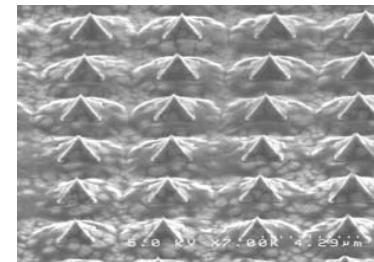


Replace solid state devices

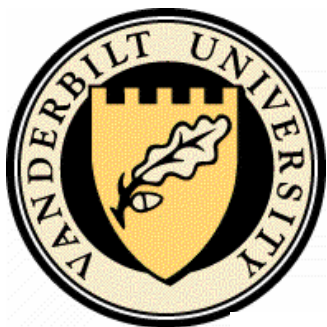
- RF/Microwave Power Devices
- Power Amplifier
- Power/Voltage Controls
 - Electric Power Industry
 - Pulsed Power Systems
 - Electric Automobile
- Plasma Contactor High
- Ion Propulsion



Single Diamond Tip



Diamond Tip Array



School of Engineering

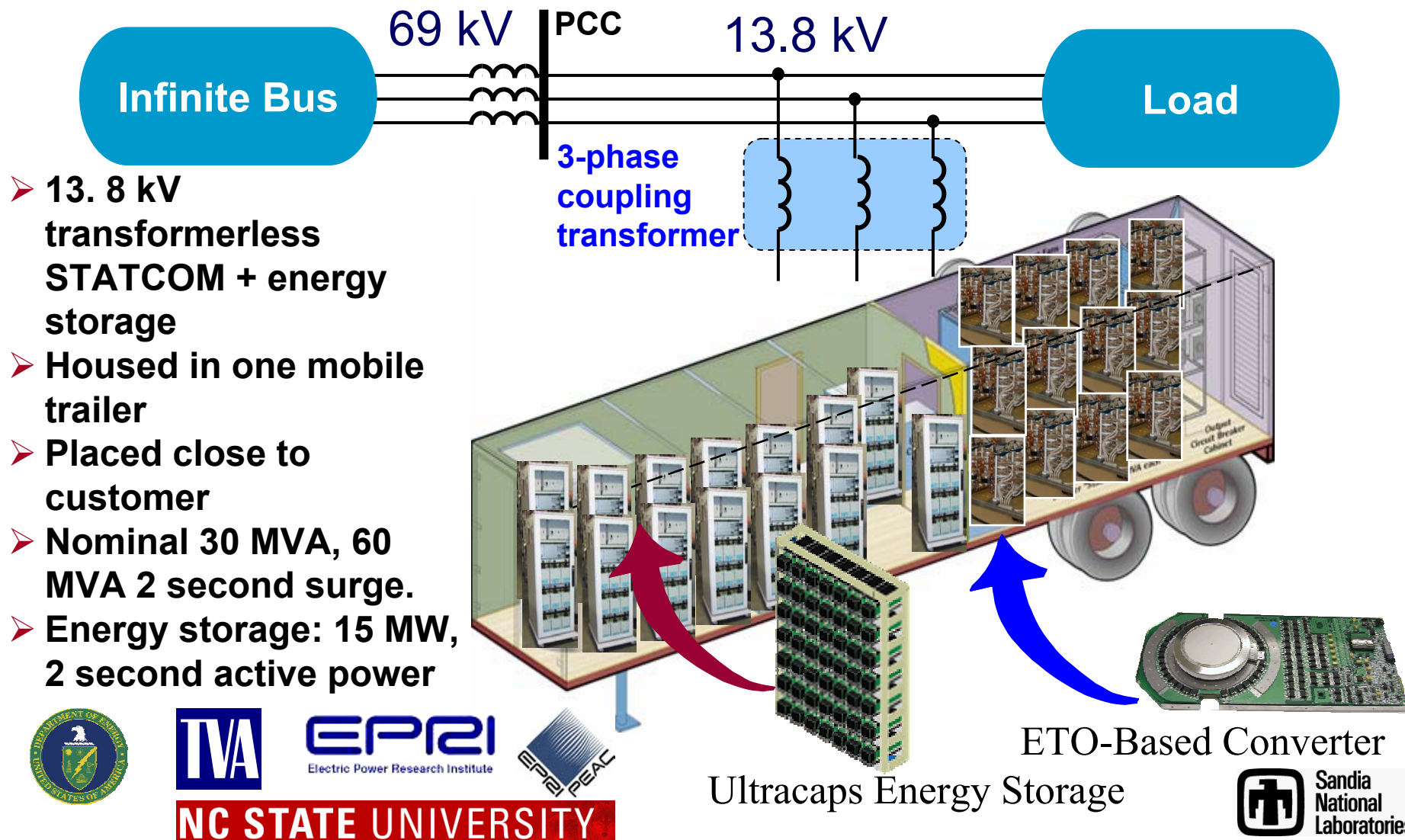
Source: Jim Davidson, Vanderbilt University



High Power Semiconductor Switch Applications

- **FACTS Controllers**
 - STATCOM, DSTATCOM, SSSC, DVR
- **Substation Uninterruptible Power Supplies**
- **Solid-State Circuit Breakers**
- **Fault-Current Limiters**
- **Solid-State Transformers**
- **Motor Drives**
- **Power Systems for Future DoD Platforms**

Emitter Turn-Off Thyristor Demonstration Project





FACTS Controllers Research

- **Flexible AC Transmission System (FACTS):** Alternating current transmission systems incorporating power electronics-based and other static controllers to enhance controllability and increase power transfer capability IEEE Definition
- **STATCOM, DSTATCOM, SSSC, DVR**
- **Current Issues**
 - **Cost**
 - Becoming competitive
 - Cost vs. Benefit vs. Cost of Alternatives
 - Regulatory issues
 - **Lifetime experience is limited**
 - Numbers are growing
 - Experience is good but need more
 - Utility Reluctance – need help on learning curve
 - **Reliability**
 - Not quite a mature technology



FACTS Controllers Research

- **EPRI Sponsored Installations**
 - Sullivan Substation (TVA, 1995)
 - Inez Substation (AEP, 1998)
 - Eagle Pass (CSW, 2000)
 - Marcy Substation (NYPA, 2000 & 2003)
- **Current Energy Storage Projects**
 - North Carolina State University ETO-based FACTS
 - University of Missouri-Rolla University-based FACTS plus Energy Storage
 - Airak, Inc. Optically isolated HVIGBT-based FACTS

ORNL's Power Electronics Research Areas



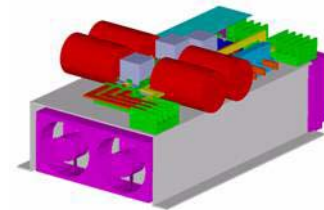
- **Interface** with distributed energy resources such as **microturbines, fuel cells, and solar cells**
- **Multilevel converters** for utility applications such as static var compensation, voltage sag support, HVDC intertie, large variable speed drives



- Harmonics, power quality, and power filters
- **Hybrid electric vehicle (HEV) applications** such as motor drives or DC-DC converters



- **Soft-switching** inverters and DC-DC converters
- Application of **wide-band gap power electronics** such as **silicon carbide (SiC)**



- **Thermal management and packaging** of power electronics especially for high-temperature environments

Source: Leon M. Tolbert, ORNL





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